AQUATIC PLANTS OF SAN DIEGO.

During the wet spring of 1884 I had an excellent opportunity to note the aquatic flora of this vicinity. Doubtless it seldom reaches such luxuriance; and in some years, owing to the scarcity of water, many of the plants certainly make no appearance.

Surface-water reached an exceedingly low stage in 1883; and San Diego was supposed remarkably free from any water-plants, except the wide-spread Azolla, and a few other well-known species. However, the heavy rains of 1884, flooding the entire country, revealed a surprisingly large variety; and that, too, where one would least expect it, — on the broad, usually dry and barren mesas.

The surface-geology of large portions of these mesas is characterized by innumerable hillocks, or small mound-like formations, rising from one to four feet above the intervening depressions, and ranging from ten to fifty feet in diameter. They are generally nearly circular, though often irregular; and the depressions contain in stony places accumulations of cobblestones.

These innumerable hollows naturally become miniature lagoons as soon as heavy rains commence; and soon the leaves of Callitriche are floating upon their surface, while the deeper portions of the little lakes are lined upon the bottom with large patches of Pilularia Americana, Tillaea angustifolia (Nutt.), and Elatine; and along the borders are other minute plants which altogether form a tangled mat of miniature luxuriance, exceeding in comparison the vegetation of the largest lakes. Some of the larger pools, longer covered with water, are filled along the edges with junci, sedges and grasses, among which, at the bottom, Isoetes thrives as well as in the northern lakes.

Later in the season, Downingia pulchella and Pogogyne nudiuscula, with several less conspicuous species, border the pools; and still later a new golden Bloomeria, blue Brodiaeas, and other beautiful Liliaceae, are found; and these, in turn, give way to a few Compositae, preceding the next dry season.

This year another plant, Marsilia vestita, common to lagoons at high altitudes, and also Ammannia latifolia (L.) and Echinodius rostratus (Engelm.), grew abundantly in this vicinity, on the borders of a usually dry flat, near the level of the sea. Other aquatics were found in great quantity throughout the country; and nearly two dozen species of common water-plants, previously unknown to this section, were added to the local flora. C. R. Orcutt.

SUNLIGHT AND THE EARTH'S ATMOSPHERE.[1]

There is, we may remember, a passage in which Plato inquires what would be the thoughts of a man who, having lived from infancy under the roof of a cavern, where the light outside was inferred only by its shadows, was brought for the first time into the full splendors of the sun. We may have enjoyed the metaphor without thinking that it has any physical application to ourselves, who appear to have no roof over our heads, and to see the sun's face daily; while the fact is, that if we do not see that we have a roof over our heads in our atmosphere, and do not think of it as one, it is because it seems so transparent and colorless.

Now, I wish to ask your attention to-night to considerations in some degree novel, which appear to me to show that it is not transparent, as it appears, and that this seeming colorlessness is a sort of delusion of our senses, owing to which we have never in all our lives seen the true color of the sun, which is in reality blue rather than white, as it looks; so that this air all about and above us is acting like a colored glass roof over our heads, or a sort of optical sieve, holding back the excess of blue in the original sunlight, and letting only the white sift down to us. I will first ask you, then, to consider that this seeming colorlessness of the air may be a delusion of our senses, due to habit, which has never given us any thing else to compare it with.

If that cave had been lit by sunshine coming through a reddish glass in its roof, would the perpetual dweller in it ever have had an idea but that the sun was red? How is he to know that the glass is 'colored,' if he has never in his life any thing to compare it with? How can he have any idea but that this is the sum of all the sun's radiations (corresponding to our idea of white or colorless light)? Will not the habit of his life confirm him in the idea that the sun is red? and will he not think that there is no color in the glass, so long as he cannot go outside to see? Has this any suggestion for us, who have none of us ever been outside our crystal roof to see? We must all acknowledge in the abstract, that habit is equally strong in us, whether we dwell in a cave or under the sky; that what we have thought from infancy will probably appear the sole possible explanation; and that, if we want to break its chain, we should put ourselves, at least in imagination, under conditions where it no longer binds us.

The Challenger has dredged from the bottom of the ocean fishes which live habitually at great depths, and whose enormous eyes tell of the correspondingly faint light which must have descended to them through the seemingly transparent water. It will not be so futile a speculation as it may at first seem, to put ourselves in imagination in the condition of creatures under the sea, and ask what the sun may appear to be to them; for, if the fish who had never

[1] A lecture delivered at the Royal institution, April 17, 1885, by Prof. S .P. Langley of Alleghany. From advance sheets of *Nature*, kindly furnished by the editor.

risen above the ocean-floor were an intelligent being, might *he* not plausibly reason that the dim greenish light of his heaven — which is all he has ever known — was the full splendor of the sun, shining through a medium which all his experience shows is transparent? We ourselves are, in very fact, living at the floor of a great aerial sea, whose billows roll hundreds of miles above our heads. Is it not, at any rate, conceivable that we may have been led into a like fallacy from judging only by what we see at the bottom? May we not, that is, have been led into the fallacy of assuming that the intervening medium above us is colorless because the light which comes through it is so?

I freely admit that all men, educated or ignorant, appear to have the evidence of their senses that the air is colorless, and that pure sunlight is white; so that, if I venture to ask you to listen to considerations which have lately been brought forward to show that it is the sun which is blue, and the air really acts like an orange veil, or like a sieve which picks out the blue and leaves the white, I do so in the confidence that I may appeal to you on other grounds than those I could submit to the primitive man, who has his senses alone to trust to; for the educated intelligence possesses those senses equally, and, in addition, the ability to interpret them by the light of reason; and before this audience it is to that interpretation that I address myself.

Permit me a material illustration. You see through this glass, which may typify the intervening medium of air or water, a circle of white light, which may represent the enfeebled disk of the sun when so viewed. Is this intervening glass colored, or not? It seems nearly colorless; but have we any right to conclude that it is so because it seems so? Are we not *taking it for granted* that the original light which we see through it is white, and that the glass is colorless because the light seems unaltered? and is not an appeal to be made here from sense to reason, which, in the educated observer, recalls that white light is made of various colors, and that whether the original light is really white and the glass transparent, or the glass really colored and so *making* the white, is to be decided only by experiment, by taking away the possibly deceptive medium? I can take away this glass, which was not colorless, but of a deep orange, and you see that the original light was not white, but intensely blue. If we could take the atmosphere away between us and the sun, how can we say that the same result might not follow? To make the meaning of our illustration clearer, observe that this blueness is not a pure spectral blue. It has in it red, yellow, blue, and all the colors which make up white, but blue in superabundance; so that, though the white is, so to say, latent there, the dominant effect is blue. The glass colored veil does not put any thing *in*, but acts, I repeat, like a sieve straining *out* the blue, and letting through to us the white light which was there in the bluishness; and so may not our air do so too?

I think we already begin to see that it is, at any rate, conceivable that we *may* have been hitherto under a delusion about the true color of the sun, though of course this is not proving that we have been so. And it will at any rate, I hope, be evident that here is a question raised which ought to be settled: for the blueness of the sun, if proven, evidently affects our present knowledge in many ways, and will modify our present views in optics, in meteorology, and in numerous other things, — in optics, because we should find that white light is *not* the sum of the sun's radiations, but only of those dregs of them which have filtered down to us; in meteorology, because it is suggested that the temperature of the globe, and the condition of man on it, depend in part on a curious selective action of our air, which picks out parts of the solar heat (for instance, that connected with its blue light), and holds them back, letting other selected portions come to us, and so altering the conditions on which this heat by which we live depends; in other ways innumerable, because, as we know, the sun's heat and light are facts of such central importance, that they affect almost every part of scientific knowledge.

It may be asked, What suggested the idea that the sun may be blue rather than any other color? My own attention was first directed this way many years ago, when measuring the heat and light from different parts of the sun's disk. It is known that the sun has an atmosphere of its own, which tempers its heat, and by cutting off certain radiations, and not others, produces the spectral lines we are all familiar with. These lines we customarily study in connection with the absorbing vapors of sodium, iron, and so forth, which produce them; but my own attention was particularly given to the regions of absorption, or to the color it caused; and I found that the sun's body must be deeply bluish, and that it would shed blue light, except for this apparently colorless solar atmosphere which really plays the part of a reddish veil, letting a little of the blue appear on the centre of the sun's disk where it is thinnest, and staining the edge red, so that to delicate tests the centre of the sun is a pale aqua-marine, and its edge a garnet. The effect I found to be so important, that, if this all but invisible solar atmosphere were diminished by but a third part, the temperature of the British Islands would rise above that of the torrid zone; and this directed my attention to the great practical importance of studying the action of our own terrestrial atmosphere on the sun, and the antecedent probability that our own air was also and independently making the really blue sun into an apparently white one. We actually know, then, beyond conjecture, by a comparison of the sun's atmosphere where it is thickest, and where it is thinnest, that an apparently colorless atmosphere *can* have such an effect; and analogous observations which I have carried on for many years, but do not now detail, show that the atmosphere of our own planet, this seemingly clear air in which we exist like creatures at the bottom of the sea, does do so. We look up through our own air as through something so limpid in its purity, that it appears scarcely matter at all; and we are apt to forget the enormous mass of what seems of such

lightness, but which really presses with nearly a ton to each square foot, so that the weight of all the buildings in this great city, for instance, is less than that of the air above them.

I hope shortly to describe the method of proof that it, too, has been acting like an optical sieve, holding back the blue; but it may naturally be asked, Can our senses have so entirely deceived us that they give no hint of this truth, if it be one? Is the appeal wholly to recondite scientific methods, and are there no indications, at least, which we may gather for ourselves? I think there are, even to our unaided eyes, indications that the seemingly transparent air really acts as an orange medium, and keeps the blue light back in the upper sky.

If I hold this piece of glass before my eyes, it seems colorless and transparent; but it is proved not to be so by looking through it edgewise, when the light, by traversing a greater extent, brings out its true color, which is yellow. Every one knows this in every-day experience. We shall not get the color of the ocean by looking at it in a wineglass, but by gazing through a great depth of it; and so it is with the air. If we look directly up, we look through where it is thinnest; but if we look horizontally through it towards the horizon, through great thicknesses, as at sunrise or sunset, is it not true that this air, where we see its real color most plainly, makes the sun look very plainly yellow or orange? We not only see here, in humid English skies, the 'orange sunset waning slow,' but most of us, in these days of travel, can perfectly testify that the clearest heavens the earth affords, the rosy tint on the snows of Mont Blanc, forerunning the dawn, or the warm glow of the sun as he sets in Egyptian skies, show this most clearly, — show that the atmosphere holds back the blue rays by preference, and lets the orange through.

If next we ask, What has become of the blue that it has stopped? does not that very blue of the mid-day sky relate the rest of the story, — that blue which Professor Tyndall has told us is due to the presence of innumerable fine particles in the air, which act selectively on the solar waves, diffusing the blue light towards us? I hope it will be understood that Professor Tyndall is in no way responsible for my own inferences; but I think it is safe, at least, to say that the sky is not self-luminous, and that, since it can only be shining blue at the expense of the sun, all the light this sky sends us has been taken by our atmosphere away from the direct solar beam, which would grow both brighter and bluer if this were restored to it.

If all that has been said so far renders it possible that the sun may be blue, you will still have a right to say that 'possibilities' and 'maybes' are not evidence, and that no chain of mere hypotheses will draw truth out of her well. We are all of one mind here, and I desire next to call your attention to what I think is evidence.

Remembering that the case of our supposed dweller in the cave who could not get outside, or that of the inhabitants of the ocean-floor who cannot rise to the surface, is really like our own, over whose heads is a crystalline roof which no man from the beginning of time has ever got outside of, — an upper sea to whose surface we have never risen, — we recognize that if we could rise to the surface, leaving the medium whose effect is in dispute wholly beneath us, we should see the sun as it is, and get proof of an incontrovertible kind; and that, if we cannot entirely do this, we shall get nearest to proof under our real circumstances by going as high as we can in a balloon, or by ascending a very high mountain. The balloon will not do, because we have to use heavy apparatus requiring a solid foundation. The proof to which I ask your kind attention, then, is that derived from the actual ascent of a remarkable mountain by an expedition undertaken for that purpose, which carried a whole physical laboratory up to a point where nearly one-half the whole atmosphere lay below us. I wish to describe the difference we found in the sun's energy at the bottom of the mountain, and at the top, and then the means we took to allow for the effect of that part of the earth's atmosphere still over our heads even here, so that we may be said to have virtually got outside it altogether.

Before we begin our ascent, let me explain more clearly what we are going to seek. We need not expect to find that the original sunlight is a pure monochromatic blue by any means, but that though its rays contain red, orange, blue, and all the other spectral colors, the blue, the violet, and the allied tints were originally there in disproportionate amounts; so that, though all which make white were present from the first, the refrangible end of the spectrum had such an excess of color, that the dominant effect was that of a bluish sun. In the same way, when I say briefly that our atmosphere has absorbed this excess of blue and let the white reach us, I mean, more strictly speaking, that this atmosphere has absorbed *all* the colors, but selectively taking out more orange than red, more green than orange, more blue than green; so that its action is wholly a taking-*out*, — an action like that which you now see going on with this sieve, sifting a mixture of blue and white beads, and holding back the blue, while letting the white fall down.

This experiment only rudely typifies the action of the atmosphere, which is discriminating and selective in an amazing degree; and, as there are really an infinite number of shades of color in the spectrum, it would take forever to describe the action in detail. It is merely for brevity, then, that we now unite the more refrangible colors under the general word 'blue,' and the others under the corresponding terms 'orange' or 'red.'

All that I have the honor to lay before you is less an announcement of absolute novelty than an appeal to your already acquired knowledge, and to your reason as superior to the delusions of sense. I have, then, no novel experiment to offer, but to ask you to look at some familiar ones in a new light. We are most of us familiar, for instance, with that devised by Sir Isaac Newton to show that white light is compounded of blue, red, and other colors, where, by

turning a colored wheel rapidly, all blend into a grayish white. Here you see the 'seven colors' on the screen; but, though all are here, I have intentionally arranged them so that there is too much blue, and the combined result is a very bluish white, which may roughly stand for that of the original sun-ray. I now alter the proportion of the colors so as to virtually take out the excess of blue, and the result is colorless or white light. White, then, is not necessarily made by combining the 'seven colors,' or any number of them, unless they are there in just proportion (which is in effect what Newton himself says); and white, then, may be made out of such a bluish light as we have described, not by putting any thing to it, but by taking away the excess which is there already.

Here, again, are two sectors, — one blue, one orange-yellow with the blue in excess, — making a bluish disk where they are revolved. I take out the excess of blue, and now what remains is white. Here is the spectrum itself on the screen, but a spectrum which has been artificially modified so that the blue end is relatively too strong. I recombine the colors (by Professor Rood's ingenious device of an elastic mirror), and they do not make a pure white, but one tinted with blue. I take out the original excess of blue, and what remains combines into a pure white. Please bear in mind that when we 'put in' blue here, we have to do so by straining out other light through some obscuring medium, which makes the spectrum darker, but that, in the case of the actual sunlight, introducing more blue introduces more light, and makes the spectrum brighter.

The spectrum on the screen ought to be made still brighter in the blue than it is, — far, far brighter, — and then it might represent to us the original solar spectrum before it has suffered any absorption either in the sun's atmosphere or our own. The Fraunhofer lines do not appear in it; for these, when found in the solar spectrum, show that certain individual rays have been stopped, or selected for absorption by the intervening atmospheres; and, though even the few yards of atmosphere between the lamp and the screen absorb, it is not enough to show.

Our spectrum, as it appears before absorption, might be compared to an army divided into numerous brigades, each wearing a distinct uniform, — one red, one green, one blue; so that all the colors are represented each by its own body. If, to represent the light absorbed as it progresses, we supposed that the army advances under a fire which thins its numbers, we should have to consider that (to give the case of nature) this destructive fire was directed chiefly against those divisions which were dressed in blue, or allied colors, so that the army was thinned out unequally, many men in blue being killed off for one in red; and that, by the time it has advanced a certain distance under fire, the proportion of the men in each brigade has been altered, the red being comparatively unhurt. Almost all absorption is thus selective in its action, and often in an astonishing degree; killing off, so to speak, certain rays in preference to others, as though by an intelligent choice, and not only destroying most of certain divisions (to continue our illustration), but even picking out certain files in each company. Every ray, then, has its own individuality, and on this I cannot too strongly insist; for just as two men retain their personalities under the same red uniform, and one may fall and the other survive, though they touch shoulders in the ranks, so in the spectrum certain parts will be blotted out by absorption, while others next to them may escape.

To illustrate this selective absorption, I put a piece of didymium glass in the path of the ray. It will, of course, absorb some of the light; but, instead of dimming the whole spectrum, we might almost say it has arbitrarily chosen to select one narrow part for action, in this particular case choosing a narrow file near the orange, and letting all the rest go unharmed. In this arbitrary way our atmosphere operates, but in a far more complex manner, taking out a narrow file here, and another there, in hundreds of places all through the spectrum, but, on the whole, much the most in the blue, the Fraunhofer lines being merely part of the evidence of this wonderful quasi-intelligent action which bears the name of selective absorption.

Before we leave this spectrum, let us recall one most important matter. We know that here, beyond the red, is solar energy in the form of heat, which we cannot see, but not on that account any less important. More than half the whole power of the sun is here invisible, and, if we are to study completely the action of our atmosphere, we shall have to pay great attention to this part, and find out some way of determining the loss in it; which will be difficult, for the ultra-red end is not only invisible, but compressed, the red end being shut up like the closed pages of a book, as you may notice by comparing the narrowness of the red with the width of the blue.

Now, refraction by a prism is not the only way of forming a spectrum. Nature furnishes us color not only from the rainbow, but from non-transparent substances, like mother-of-pearl, where the irridescent hues are due to microscopically fine lines. Art has lately surpassed nature in these wonderful 'gratings,' consisting of pieces of polished metal, in which we see at first nothing to account for the splendid play of color apparently pouring out from them like light from an opal, but which, on examination with a powerful microscope, show lines so narrow that there are from fifty to a hundred in the thickness of a fine human hair, and all spaced with wonderful precision.

This grating is equal in defining-power to many such prisms as we have just been looking at, but its light does not show well upon the screen. You will see, however, that its spectrum differs from that of the prism, in that in this case the red end is expanded, as compared with the violet, and the invisible ultra-red is expanded still more; so that this will be the best means for us to use in exploring that 'dark continent' of invisible heat found in the spectrum not only of the sun, but of the electric light, and of all incandescent bodies, and of whose existence we already know from Herschel and Tyndall.

Now, we cannot reproduce the actual solar spectrum

on the screen, without the sun itself; but here are photographs of it, which show parts of the losses the different colors have suffered on their way to us. We have before us the well-known Fraunhofer lines, due, you remember, not only to absorption in the sun's atmosphere, but also to absorption in our own. We have been used to think of them in connection with their cause, one being due to the absorption of iron-vapor in the sun, another to that of water-vapor in our own air, and so forth; but now I ask you to think of them only in connection with the fact that each is due to the absorption of some part of the original *light*, and that collectively they tell much of the story of what has happened to that light on its way down to us. Observe, for instance, how much thicker they lie in the blue end than in the red, — another evidence of the great proportionate loss in the blue.

If we could restore all the lost light in these lines, we should get back partly to the original condition of things at the very fount; and, so far as our own air is concerned, that is what we are to ascend the mountain for, — to see, by going up through nearly half of the atmosphere, what the rate of loss is in each ray by actual trial; then, knowing this rate, to be able to allow for the loss in the other part still above the mountain-top; and, finally, by recombining these rays, to get the loss as a whole. Remember, however, always, that the most important part of the solar energy is in the dark spectrum, which we do not see, but which, if we could see, we should probably find to have numerous absorption-spaces in it corresponding to the Fraunhofer lines, but where heat has been stopped out rather than light. To make our research thorough, then, we ought not to trust to the eye only, or even chiefly, but have some way of investigating the whole spectrum, — the invisible, in which the sun's power chiefly lies, as well as the visible, and both with an instrument that would discriminate the energy in these very narrow spaces like an eye to see in the dark; and, if science possesses no such instrument, then it may be necessary to invent one.

The linear thermopile is nearest to it of any, and we all here know what good work it has done; but even that is not sensitive enough to measure in the grating spectrum, in some parts of which the heat is four hundred times weaker than in that of a prism, and we want to observe this invisible heat in very narrow spaces. Something like this has been provided since by Capt. Abney's most valuable researches; but these did not at the time go low enough for my purpose, and I spent nearly a year, before ascending the mountain, in inventing and perfecting the new instrument for measuring these, which I have called the 'bolometer,' or 'ray-measurer.' The principle on which it is founded is the same as that employed by my late lamented friend, Sir William Siemens, for measuring temperatures at the bottom of the sea, which is, that a smaller electric current flows through a warm wire than through a cold one.

One great difficulty was to make the conducting-wire very thin, and yet continuous; and for this purpose, almost endless experiments were made; among other substances, pure gold having been obtained by chemical means in a plate so thin that it transmitted a sea-green light through the solid substance of the metal. This proving unsuitable, I learned that iron had been rolled of extraordinary thinness in a contest of skill between some English and American iron-masters; and, procuring some, I found that fifteen thousand of the iron plates they had rolled, laid one on the other, would make but one English inch. Here is some of it, rolled between the same rolls which turn out plates for an iron-clad, but so thin, that, as I let it drop, the iron plate flutters down like a dead leaf. Out of this the first bolometers were made; and I may mention that the cost of these earlier experiments was met from a legacy by the founder of the Royal institution, Count Rumford. The iron is now replaced by platinum, in wires, or rather tapes, from a two-thousandth to a twenty-thousandth of an inch thick, one of which is within this button, where it is all but invisible, being far finer than a human hair. I will project it on the screen, placing a common small pin beside it as a standard of comparison. This button is placed in this ebonite case, and the thread is moved by this micrometer screw, by which it can be set like the spider-line of a reticule; but by means of this cable, connecting it to the galvanometer, this thread acts as though sensitive, like a nerve laid bare to every indication of heat and cold. It is, then, a sort of sentient thing: what the eye sees as light it feels as heat, and what the eye sees as a narrow band of darkness (the Fraunhofer line) this feels as a narrow belt of cold; so that, when moved parallel to itself and the Fraunhofer lines down the spectrum, it registers their presence.

It is true, we can see these in the visible spectrum. But you remember, we propose to explore the invisible also; and, since to this the dark is the same as the light, it will feel absorption-lines in the infra-red which might remain otherwise unknown.

I have spent a long time in these preliminary researches, in indirect methods for determining the absorption of our atmosphere, and in experiments and calculations which I do not detail; but it is so often supposed that scientific investigation is a sort of happy guessing, and so little is realized of the labor of preparation and proof, that I have been somewhat particular in describing the essential parts of the apparatus finally employed; and now we must pass to the scene of their use.

We have been compared to creatures living at the bottom of the sea, who frame their deceptive traditional notions of what the sun is like from the feeble, changed rays which sift down to them. Though such creatures could not rise to the surface, they might swim up towards it; and if these rays grew hotter, brighter, and bluer, as they ascended, it would be almost within the capacity of a fish's mind to guess that they are still brighter and bluer at the top. Since we children of the earth, while dwelling on it, are always at the bottom of a sea, though of another sort, the most direct method of proof I spoke of, is merely

to group as far as we can, and observe what happens; though, as we are men, and not fishes, something more may fairly be expected of our intelligence than of theirs.

We will not only guess, but measure and reason; and in particular we will first, while still at the bottom of the mountain, draw the light and heat out into a spectrum, and analyze every part of it by some method that will enable us to explore the invisible, as well as record the visible. Then we will ascend many miles into the air, meeting the rays on the way down, before the sifting process has done its whole work, and there analyze the light all over again, so as to be able to learn the different proportions in which the different rays have been absorbed, and, by studying the action on each separate ray, to prove the state of things which must have existed before this sifting — this selective absorption — began.

It may seem at first that we cannot ascend far enough to do much good, since the surface of our aerial ocean is hundreds of miles overhead; but we must remember that the air grows thinner as we ascend, the lower atmosphere being so much denser that about one-half the whole substance or mass of it lies within the first four miles, which is a less height than the tops of some mountains. Every high mountain, however, will not do: for ours must not only be very high, but very steep; so that the station we choose at the bottom may be almost under the station we are afterwards to occupy at the top. Besides, we are not going to climb a lofty, lonely summit, like tourists, to spend an hour, but to spend weeks; so that we must have fire and shelter, and, above all, we must have dry air to get clear skies. First I thought of the Peak of Teneriffe; but afterwards some point in the territories of the United States seemed preferable, particularly as the government offered to give the expedition, through the signal-service, and under the direction of its head, Gen. Hazen, material help in transportation, and a military escort, if needed, anywhere in its own dominions. No summit in the eastern part of the United States rises much over seven thousand feet, and, though the great Rocky Mountains reach double this, their tops are the home of fog and mist; so that the desired conditions, if met at all, could only be found on the other side of the continent, in southern California, where the summits of the Sierra Nevadas rise precipitously out of the dry air of the great wastes in lonely peaks, which look eastward down from a height of nearly fifteen thousand feet upon the desert lands.

This remote region was, at the time I speak of, almost unexplored; and its highest peak, Mount Whitney, had been but once or twice ascended, but was represented to be all we desired, could we once climb it. As there was great doubt whether our apparatus, weighing several thousand pounds, could possibly be taken to the top, and we had to travel three thousand miles even to get where the chief difficulties would begin, and make a desert journey of a hundred and fifty miles after leaving the cars, it may be asked why we committed ourselves to such an immense journey, to face such unknown risks of failure. The answer must be, that mountains of easy ascent, and fifteen thousand feet high, are not to be found at our doors, and that these risks were involved in the nature of our novel experiment; so that we started out from no love of mere adventure, but from necessity, much into the unknown. The liberality of a citizen of Pittsburgh, to whose encouragement the enterprise was due, had furnished the costly and delicate apparatus for the expedition; and that of the transcontinental railroads enabled us to take this precious freight along in a private car, which carried a kitchen, a steward, a cook, and an ample larder besides.

In this we crossed the entire continent from ocean to ocean, stopped at San Francisco for the military escort, went three hundred miles south so as to get below the mountains, and then turned eastward again on to the desert, with the Sierras to the north of us, after a journey which would have been unalloyed pleasure except for the anticipation of what was coming as soon as we left our car. I do not, indeed, know that one feels the triumphs of civilization over the opposing forces of nature anywhere more than in the sharp contrasts which the marvellous luxury of recent railroad accommodation gives to the life of the desert. When one is in the centre of one of the great barren regions of the globe, and, after looking out from the windows of the flying train on its scorched wastes for lonely leagues of habitless desolation, turns to his well-furnished dinner-table, and the fruit and ices of his dessert, he need not envy the heroes of oriental story who were carried across dreadful solitudes in a single night on the backs of flying genii. Ours brought us over three thousand miles to the Mojave desert. It was growing hotter and hotter when the train stopped in the midst of vast sand-wastes a little after midnight. Roused from our sleep, we stepped on to the brown sand, and saw our luxurious car roll away in the distance, experiencing a transition from the conditions of civilization to those almost of barbarism, as sharp as could well be imagined. We commenced our slow toil northward with a thermometer at 110° in the shade, if any shade there be in the shadeless desert, which seemed to be chiefly inhabited by rattlesnakes of an ashen gray color and a peculiarly venomous bite. There is no water save at the rarest intervals; and the soil at a distance seems as though strewed with sheets of salt, which aids the delusive show of the mirage. These are, in fact, the ancient beds of dried-up salt lakes or dead seas, some of them being below the level of the ocean; and such a one on our right, though only about twenty miles wide, has earned the name of 'Death Valley,' from the number of human beings who have perished in it. Formerly an emigrant-train, when emigrants crossed the continent in caravans, had passed through the great Arizona deserts in safety, until, after their half-year's journey, their eyes were gladdened by the snowy peaks of the Sierras looking delusively near. The goal of their long toil seemed before them: only this one more valley lay between; and into this they descended, thinking to cross it in a day, but they never crossed it. Afterwards the long line of wagons was found, with the skeletons of the animals in the

harness, and by them those of men, women, and little children, dead of thirst; and some relics of the tragedy remained at the time of our journey. I cite this as an indirect evidence of the phenomenal dryness of the region, — a dryness which so far served our object, which was, in part, to get rid, as much as possible, of that water-vapor which is so well known to be a powerful absorber of the solar heat.

Every thing has an end; and so had that journey, which finally brought us to the goal of our long travel at the foot of the highest peak of the Sierras, Mount Whitney, which rose above us in tremendous precipices that looked hopelessly insurmountable and wonderfully near. The whole savage mountain region, in its slow rises from the west, and its descent to the desert plains in the east, is more like the chain called the Apennines, in the moon, than any thing I know on the earth. The summits are jagged peaks, like Alpine 'needles,' looking in the thin air so delusively near, that, coming on such a scene unprepared, one would almost say they were large gray stones a few fields off, with an occasional little white patch on the top that might be a handkerchief or a sheet of paper dropped there. But the telescope showed that the seeming stones were of the height of many Snowdons piled on one another, and the white patches occasional snow-fields, looking how invitingly cool from the torrid heat of the desert, where we were encamped by a little rivulet that ran down from some unseen ice-lake in that upper air. Here we pitched our tents, and fell to work (for you remember we must have two stations, a low and a high one, to compare the results); and here we labored three weeks in almost intolerable heat, the instruments having to be constantly swept clear of the red desert dust which the hot wind brought. Close by these tents, a thermometer covered by a single sheet of glass, and surrounded by wool, rose to 237° in the sun; and sometimes in the tent, which was darkened for the study of separate rays, the heat was absolutely beyond human endurance. Finally, our apparatus was taken apart, and packed in small pieces on the backs of mules, who were to carry it by a ten-days' journey through the mountains to the other side of the rocky wall, which, though only ten or twelve miles distant, arose miles above our heads; and, leaving these mule-trains to go with the escort by this longer route, I started with a guide by a nearer way to those white gleams in the upper skies that had daily tantalized us below in the desert with suggestions of delicious, unattainable cold. That desert sun had tanned our faces to a leather-like brown, and the change to the cooler air as we ascended was at first delightful. At an altitude of five thousand feet we came to a wretched band of nearly naked savages, crouched around their camp-fire, and at six thousand found the first scattered trees; and here the feeble suggestion of a path stopped, and we descended a ravine to the bed of a mountain stream, up which we forced our way, cutting through the fallen trees with an axe, fighting for every foot of advance, and finally passing what seemed impassable. It was interesting to speculate as to the fate of our siderostat mirrors and other precious freight, now somewhere on a similar road, but quite useless. We were committed now, and had to make the best of it; and, besides, I had begun to have my attention directed to a more personal subject. This was, that the colder it grew, the more the sun burnt the skin — quite literally burnt, I may say; so that by the end of the third day my face and hands, case-hardened, as I thought, in the desert, began to look as if they had been seared with red-hot irons, here in the cold, where the thermometer had fallen to freezing at night; and still, as we ascended, the paradoxical effect increased. The colder it grew about us, the hotter the sun blazed above. We have all heard, probably, of this curious effect of burning in the midst of cold, and some of us may have experienced it in the Alps, where it may be aided by reflection from the snow, which we did not have about us at any time except in scattered patches; but here, by the end of the fourth day, my face was scarcely recognizable, and it almost seemed as though sunbeams up here were different things, and contained something which the air filters out before they reach us in our customary abodes. Radiation here is increased by the absence of water-vapor, too; and, on the whole, this intimate personal experience fell in almost too well with our anticipations that the air is an even more elaborate trap to catch the sunbeams than had been surmised, and that this effect of selective absorption and radiation was intimately connected with that change of the primal energies and primal color of the sun which we had climbed towards it to study.

On the fourth day, after break-neck ascents and descents, we finally ascended by a ravine down which leaped a cataract, till, at nightfall, we reached our upper camp, which was pitched by a little lake, one of the sources of the waterfall, at a height of about twelve thousand feet, but where we seemed in the bottom of a valley, nearly surrounded as we were by an amphitheatre of rocky walls which rose perpendicularly to the height of Gibraltar from the sea, and cut off all view of the desert below, or even of the peak above us. The air was wonderfully clear; so that the sun set in a yellow rather than an orange sky, which was reflected in the little ice-rimmed lakes, and from occasional snow-fields on the distant waste of lonely mountain summits on the west.

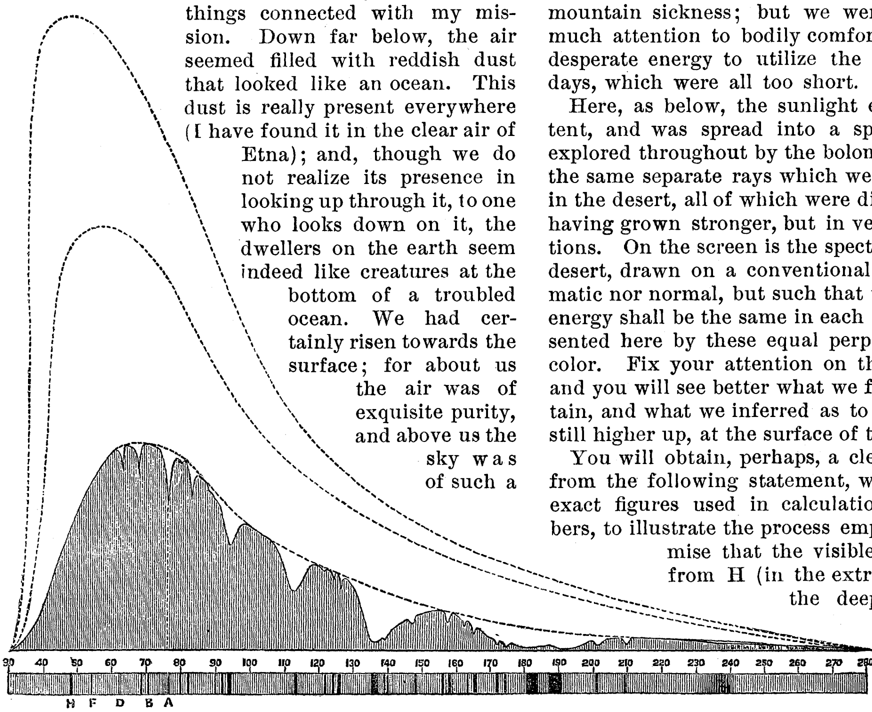
The mule-train, sent off before by another route, had not arrived when we got to the mountain camp, and we realized that we were far from the appliances of civilization by our inability to learn about our chief apparatus; for here, without post or telegraph, we were as completely cut off from all knowledge of what might be going on with it in the next mountain ravine as a ship at sea is of the fate of a vessel that sailed before from the same port. During the enforced idleness, we ascended the peak nearly three thousand feet above us, with our lighter apparatus, leaving the question of the ultimate use of the heavy ones to be settled later. There seemed little prospect of carrying it up, as we climbed where the granite walls had been split by the earthquakes, letting a stream of great rocks, like a stone river, flow down through the interstices by which we ascended; and,

in fact, the heavier apparatus was not carried above the mountain camp.

The view from the very summit was over numberless peaks on the west to an horizon, fifty miles away, of unknown mountain-tops; for, with the exception of the vast ridge of Mount Tyndall, and one or two less conspicuous ones, these summits are not known to fame; and, wonderful as the view may be, all the charm of association with human interest which we find in the mountain landscape of older lands is here lacking. It was impossible not to be impressed with the savage solitude of this desert of the upper air, and our remoteness from man and his works; but I turned to the study of the special things connected with my mission. Down far below, the air seemed filled with reddish dust that looked like an ocean. This dust is really present everywhere (I have found it in the clear air of Etna); and, though we do not realize its presence in looking up through it, to one who looks down on it, the dwellers on the earth seem indeed like creatures at the bottom of a troubled ocean. We had certainly risen towards the surface; for about us the air was of exquisite purity, and above us the sky was of such a deep violet-blue as I have never seen in Egypt or Sicily: and yet even this was not absolutely pure, for, separately invisible, the existence of fine particles could yet be inferred from their action on the light near the sun's edge; so that even here we had not got absolutely above that dust-shell which seems to encircle our whole planet. But we certainly felt ourselves not only in an upper, but a different region. We were on the ridge of the continent; and the winds which tore by had little in common with the air below, and were bearing past us (according to the geologists) dust which had once formed part of the soil of China, and been carried across the Pacific Ocean: for here we were lifted into the great encircling currents of the globe, and, 'near to the sun in lonely lands,' were in the right conditions to study the differences between his rays at the surface, and at the bottom of that turbid sea where we had left the rest of mankind. We descended the peak, and hailed with joy the first arrival of our mule-trains with the requisite apparatus at the mountain camp, and found that it had suffered less than might be expected, considering the pathless character of the wilderness. We went to work to build piers, and mount telescopes and siderostats, in the scene shown by the next illustration on the screen, taken from a sketch of my own, where these rocks in the immediate foreground rise to thrice the height of St. Paul's. We suffered from cold (the ice forming three inches deep in the tents at night) and from mountain sickness; but we were too busy to pay much attention to bodily comfort, and worked with desperate energy to utilize the remaining autumn days, which were all too short.

Here, as below, the sunlight entered a darkened tent, and was spread into a spectrum, which was explored throughout by the bolometer, measuring on the same separate rays which we had studied below in the desert, all of which were different up here, all having grown stronger, but in very different proportions. On the screen is the spectrum as seen in the desert, drawn on a conventional scale, neither prismatic nor normal, but such that the intensity of the energy shall be the same in each part, as it is represented here by these equal perpendiculars in every color. Fix your attention on these three as types, and you will see better what we found on the mountain, and what we inferred as to the state of things still higher up, at the surface of the aerial sea.

You will obtain, perhaps, a clearer idea, however, from the following statement, where I use, not the exact figures used in calculation, but round numbers, to illustrate the process employed. I may premise that the visible spectrum extends from H (in the extreme blue) to A (in the deepest red), or from near 40 (the ray of forty hundred-thousandths of a millimetre in wave-length) to near 80. All below 80, to the right, is the invisible infra-red spectrum. Now, the shaded curve above the spectrum represents the amount of energy in the sun's rays at the foot of the mountain, and was obtained in this way: Fix your attention for a moment on any single part of the spectrum; for instance, that whose wave-length is 60. If the heat in this ray, as represented by the bolometer at the foot of the mountain, was (let us suppose) 2°, on any arbitrary scale we draw a vertical line, two inches or two feet high, over that part of the spectrum. If the heat at another point, such as 40, were but $\frac{1}{5}$°, a line would be drawn there a quarter of an inch high; and so on, till these vertical lines mark out the shaded parts of the drawing, the gaps and depressions in whose outline correspond to the 'cold bands' already spoken of. Again: if on top



DISTRIBUTION OF SOLAR ENERGY AT SEA-LEVEL AND AT VARIOUS ALTITUDES.

of the mountain we measure all these over once more, we shall find all are hotter; so that we must up there make all our lines higher, but *in very different proportions.* At 60, for instance, the heat (and light) may have grown from 2° to 3°, or increased one-half, while above 40 the heat (and light) may have grown from $\frac{1}{5}$° to 1°, or increased five times. These mountain measurements give another spectrum, the energies in each part of which are defined by the middle dotted line, which we see indicates very much greater energy, whether heat or light, in the blue end than below. Next, the light or heat which would be observed at the surface of the atmosphere is found in this way. If the mountain top rises through one-half the absorbing mass of this terrestrial atmosphere (it does not quite do so, in fact), and by getting rid of that lower half the ray 60 has grown in brightness from 2 to 3, or half as much again, in going up to the top it would gain half as much more, or become $4\frac{1}{2}$; while the ray near 40, which has already increased to five times what it was, would increase five times more, or to 25. Each separate ray increasing thus nearly in some geocentric progression (though the heat, as a whole, does not), you see how we are able, by repeating this process at every point, to build up our outer or highest curve, which represents the light and heat at the surface of the atmosphere. These have grown out of all proportion at the blue end, as you see by the outer dotted curve, and now we have attained by actual measurement that evidence which we sought; and by thus reproducing the spectrum outside the atmosphere, and then recombining the colors by like methods to those you have seen on the screen, we finally get the true color of the sun, which tends, broadly speaking, to blue.

It is so seldom that the physical investigator meets any novel fact quite unawares, or finds any thing except that in the field where he is seeking, that he must count it an unusual experience to come unexpectedly on even the smallest discovery. This experience I had on one of the last days of work on the spectrum on the mountain. I was engaged in exploring that great invisible heat-region still but so partially known, or, rather, I was mapping in that great 'dark continent' of the spectrum, and by the aid of the exquisite sky and the new instrument (the bolometer) found I could carry the survey farther than any had been before. I substituted the prism for the grating, and measured on in that unknown region till I had passed the Ultima Thule of previous travellers, and finally came to what seemed the very end of the invisible heat-spectrum, beyond what had previously been known. This was in itself a return for much trouble, and I was about rising from my task, when it occurred to me to advance the bolometer still farther; and I shall not forget the surprise and emotion with which I found new and yet unrecognized regions below, — a new invisible spectrum beyond the farthest limits of the old one.

I will anticipate here by saying, that, after we got down to lower earth again, the explorations and mapping of this new region was continued. The amount of solar energy included in this new extension of the invisible region is much less than that of the visible spectrum; while its length upon the wave-length scale is equal to all that previously known, visible and invisible, as you will see better by this view, having the same thing on the normal as well as the prismatic scale. If it be asked which of these is correct, the answer is, Both of them. Both, rightly interpreted, mean just the same thing; but in the lower one we can more conveniently compare the ground of the researches of others with these. These great gaps I was at first in doubt about; but more recent researches at Alleghany make it probable that they are caused by absorption in our own atmosphere, and not in that of the sun.

We would gladly have staid longer, in spite of physical discomfort; but the formidable descent and the ensuing desert journey were before us, and certainly the reign of perpetual winter around us grew as hard to bear as the heats of the desert summer had been. On Sept. 10 we sent our instruments and the escort back by the former route, and, ourselves unencumbered, started on the adventurous descent of the eastern precipices by a downward climb, which, if successful, would carry us to the plains in a single day. I at least shall never forget that day, nor the scenery of more than Alpine grandeur which we passed in our descent, after first climbing by frozen lakes in the northern shadow of the great peak, till we crossed the eastern ridges, through a door so narrow that only one could pass it at a time, by clinging with hands and feet as he swung round the shoulder of the rocks — to find that he had passed in a single minute from the view of winter to summer, the prospect of the snowy peaks behind shut out, and instantly exchanged for that below of the glowing valley and the little oasis, where the tents of the lower camp were still pitched, the tents themselves invisible, but the oasis looking like a green scarf dropped on the broad floor of the desert. We climbed still downward by scenery unique in my recollection. This view of the ravine on the screen is little more than a memorandum made by one of the party in a few minutes' halt part way down, as we followed the ice-stream between the tremendous walls of the defile which rose two thousand feet, and between which we still descended, till, toward night, the ice-brook had grown into a mountain torrent, and, looking up the long vista of our day's descent, we saw it terminated by the peak of Whitney, once more lonely in the fading light of the upper sky.

This site, in some respects unequalled for a physical observatory, is likely, I am glad to say, to be utilized; the president of the United States having, on the proper representation of its value to science, ordered the reservation, for such purposes, of an area of a hundred square miles about and inclusive of Mount Whitney.

There is little more to add about the journey back to civilization, where we began to gather the results of our observation, and to reduce them; to smelt, so to speak, the metal from the ore we had brought home, — a slow but necessary process, which has occupied a large part of two years. The results, stated

in the broadest way, mean that the sun is blue, but mean a great deal more than that; this blueness in itself being, perhaps, a curious fact only, but, in what it implies, of practical moment. We deduce in connection with it a new value of the solar heat, so far altering the old estimates, that we now find it capable of melting a shell of ice sixty yards thick annually over the whole earth, or, what may seem more intelligible in its practical bearings, of exerting over one-horse power for each square yard of the normally exposed surface. We have studied the distribution of this heat in a spectrum whose limits on the normal scale our explorations have carried to an extent of rather more than twice what was previously known, and we have found that the total loss by absorption from the atmosphere is nearly double what has been heretofore supposed. We have found it probable that the human race owes its existence and preservation to the heat-storing action of the atmosphere even more than has been believed.

The direct determination of the effect of water-vapor in this did not come within our scope; but that the importance of the blanketing action of our atmospheric constituents has been in no way over-stated, may be inferred when I add that we have found by our experiments, that, if the planet were allowed to radiate freely into space, without any protecting veil, its sunlit surface would probably fall, even in the tropics, below the temperature of freezing mercury.

I will not go on enumerating the results of these investigations; but they all flow from the fact, which they in turn confirm, that this apparently limpid sea above our heads, and about us, is carrying on a wonderfully intricate work on the sunbeam, and on the heat returned from the soil, picking out selected parts in hundreds of places, sorting out incessantly at a task which would keep the sorting demons of Maxwell busy, and, as one result, changing the sunbeam on its way down to us in the way we have seen.

I have alluded to the practical utilities of these researches: but, practical or not, I hope we may feel that such facts as we have been considering about sunlight and the earth's atmosphere may be stones useful in the future edifice of science; and that, if not in our own hands, then in those of others when our day is over, they may find the best justification for the trouble of their search in the fact that they prove of some use to man.

May I add an expression of my personal gratification in the opportunity with which you have honored me of bringing these researches before the Royal institution, and my thanks for the kindness with which you have associated yourselves for an hour, in retrospect at least, with that climb toward the stars which we have made together, to find from light in its fulness what unsuspected agencies are at work to produce for us the light of common day.

NOTES AND NEWS.

THE Committee on meteorology, instituted by the International congress of meteorology, will meet for a third session in Paris in the beginning of the coming September. Up to the present time, the following questions have been proposed for consideration during this session: 1°. Report of the secretary on the labors of the committee since the meeting at Copenhagen; 2°. Report of Messrs. Brito Capello, Hildebrandsson, and Ley, on the observation of the cirrus; 3°. Does it seem opportune to soon convene a third international congress of meteorologists? 4°. Establishment of stations of the first order on the Kongo; 5°. Discussion on the utility of the summaries of the state of the weather as published in the different countries, and the eventual preparation of a plan for more uniformity; 6°. Discussion of the utility of the meteorological telegrams from America proposed by Gen. Hazen, and of an eventual organization for their distribution in Europe; 7°. By what means can the timely receipt of meteorological telegrams be assured? 8°. Should the reduction of barometer readings to gravity under 45° of latitude be generally introduced? 9°. Is it desirable to also count in meteorology the hours of the day from 1 h. to 24 h. according to the resolutions of the international conference in Washington? 10°. Designation for a uniformly covered sky according to the form of the clouds; 11°. Definition of rain and snow days; 12°. Should not the general adoption of a uniform height above the earth for rain-gauges be recommended? 13°. What progress has been made lately in the more exact measurement of snow; 14°. International meteorological tables; 15°. Modification of the rules for the administration of the international committee. Any meteorologists intending to submit to the committee remarks on one or the other of these questions, or to propose other questions, can address Mr. Robert H. Scott, Meteorological office, 116 Victoria Street, London.

— The French Academy of inscriptions and belles-lettres offers the Bordin prize in 1887 for the best treatment of the subject, 'A critical examination of the geography of Strabo.' Competitors are invited, 1°, to review the history of the constitution of the text of the work; 2°, to compare the language of Strabo with that of contemporaneous Greek writers, such as Diodorus Siculus, etc.; 3°, to classify the original observations of Strabo, and segregate them from such as are merely quoted by him from other authorities; 4°, to draw such definite conclusions as the above-mentioned studies may suggest. The memoirs, under the usual conditions, should be deposited with the secretary of the academy at Paris by the 31st of December, 1886.

— The fifth German geographical congress was held at Hamburg, April 9–11 last, under the auspices of a local committee.

— A meeting of the American metrological society was held at Columbia college on Wednesday, May 20. Several interesting communications were made.

— The *Geographisches jahrbuch* (Gotha), now edited by H. Wagner since the death of its founder, Behn, will hereafter appear in two annual parts, with alternating contents, instead of as a single volume every two years, as heretofore. The part of volume x. just